MATERNAL MORTALITY IN TAMIL NADU DURING 2001-10: VARIED PROGRESS IN REDUCING MATERNAL MORTALITY AT THE HEALTH DISTRICT LEVEL AND PREVENTABLE CAUSES REMAIN UNCHANGED

By

K.Kolandaswamy

(MAE- FETP Scholar July 2008- June 2010, 8th Cohort)

Submitted in partial fulfilment of the requirements for the degree of

Master of Applied Epidemiology (M.A.E) of

SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY,

Thiruvananthapuram, Kerala - 695 011.

This work has been done as part of the two-year Field Epidemiology Training Programme (FETP) leading to MAE conducted at

National Institute of Epidemiology,

(Indian Council of Medical Research),

Ayapakkam, Chennai-600 077, Tamilnadu

June 2010

MATERNAL MORTALITY IN TAMIL NADU DURING 2001-10: VARIED PROGRESS IN REDUCING MATERNAL MORTALITY AT THE HEALTH DISTRICT LEVEL AND PREVENTABLE CAUSES REMAIN UNCHANGED

By

K.Kolandaswamy

(MAE- FETP Scholar July 2008- June 2010, 8th Cohort)

Submitted in partial fulfilment of the requirements for the degree of

Master of Applied Epidemiology (M.A.E) of

SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY,

Thiruvananthapuram, Kerala - 695 011.

This work has been done as part of the two-year Field Epidemiology Training Programme (FETP) leading to MAE conducted at

National Institute of Epidemiology,

(Indian Council of Medical Research),

Ayapakkam, Chennai-600 077, Tamilnadu

June 2010

CERTIFICATION

This is to certify that the dissertation project entitled **"Maternal mortality in Tamil Nadu during 2001-10: Varied progress in reducing maternal mortality at the health district level and preventable causes remain unchanged"** submitted by **Dr.K.Kolandaswamy,** in partial fulfillment of the requirements for the degree of Master of Applied Epidemiology, is original work done by him and has not been submitted earlier, in part or whole, for any other (publication or degree) purpose.

Director,

Date: **National Institute of Epidemiology,**

(ICMR), Chennai.

ACKNOWLEDGEMENT

Several dignitaries have extended their valuable time, guidance and assistance to me during preparation of this thesis. I extend with gratitude my sincere thanks to:

Thiru.V.K.Subburaj.I.A.S, Principal Secretary to the Government, Health and Family Welfare Department, Government of Tamil Nadu for permitting me to join MAE course and his guiding spirit as a role model to improve public health systems in the state.

Mrs.Girija Vaidyanadhan.I.A.S, Principal Secretary/ Special Commissioner for MCH and Welfare, Mission Director, SRHM, State Health Society, Tamil Nadu, **Dr.S.Vijaya Kumar.I.A.S,** Project Director, Tamil Nadu Health Systems Project, **Dr.P.Padmanaban,** NRHM National Consultant and former Director of Public Health and Preventive Medicine, Tamil Nadu and **Dr.P.Nandagopalsamy,** Director of Medical Services for their encouragement and support to take up the projects in the field of maternal health.

Dr.R.T.Porkaipandian, Director of Public Health and Preventive Medicine for his dynamic initiatives to transform the research findings into reality.

Dr.V.KumaraSwami, Director-in-Charge, National Institute of Epidemiology for his dynamic leadership in providing an enabling environment for the scholars.

Dr.Manoj V. Murekhar, Scientist F, Course Coordinator, for his admirable guidance and excellence in conducting the course.

Dr.B.N.Murthy, Scientist F, Head of Biostatistics and his team **Dr.V.Selvaraj, Thiru.P.Kamaraj** and **Thiru.K.Boopathy,** Experts in Biostatistics for their excellent guidance for data analysis and interpretation.

Thiru.A.Elangovan Scientist E and his EDP team members **Thiru.K.Kanagasabai, Thiru.M.Ravi** and **Thiru.B.K.Kirubakaran** for their excellent and enthusiastic guidance in learning the statistical softwares and support for data management.

Dr.P.Manickam Scientist B, my mentor for the MAE course, for his visionary guidance and untiring efforts, right from identifying the topic to the completion and applications in the field for improving the health and well being of the mothers and their children.

Dr.R.Ramakrishnan Scientist E, **Dr.Vidya Ramachandran** Scientist E, **Dr.S.Thilakavathi** Scientist E, **Dr.Tarun Bhatnagar** Scientist C and all other faculty for their guidance and encouragement.

Mr.S.Sathish, Librarian and his team for providing us with the required reading materials.

Mr.N.K.S.Brahaspathy, Mrs.Uma Manoharan, Mr.R.Balakrishnan, Mr.T.Jegan and other office staff for their excellent secretarial support and care.

Dr.Capt.M.Kamatchi, Expert Advisor, Tamil Nadu Health Systems Project, **Dr.A.K.Rajendran,** Additional Director, Tamil Nadu State Health Society, **Dr.P.Kannan,** Additional Director (PHCs), **Dr.G.K.Durairaj,** Additional Director (Vector Borne Diseases Control) for their kind support and encouragement.

Dr.N.S.Iyer and **Prof.Dr.S.Rathnakumar** maternal health experts for their guidance and constant support.

Dr.G.Thamarai Selvi, Deputy Director, Institute of Public Health, Poonamallee, **Dr.S.Sampath,** DDHS, Thiruvallur, **Dr.A.Somasundaram,** Deputy Director (Research), **Dr.B.Shanthy,** Health Officer, State Health Society, **Thiru. P.Muniappan,** Senior Statistical Expert, TNHSP, **Thiru.P.Doraisamy,** Joint Director, State Bureau of Health Intelligence, **Mrs.T.Gnana Glory Leol,** Assistant Director-SBHI, **Thiru.N.Mani,** Assistant Director-SBHI, **Thiru.V.P.Natarajan,** Assistant Director-SBHI, **Thiru. P.T. Nambi Azhagappan,** Statistician cum system specialist, Directorate of Public Health and Preventive Medicine, **Thiru.C.Muthusamy,** State Demographer, Directorate of Family welfare, **Mrs.W.Beaula Indirani, MCHO,** and **Mrs.P.Shanthi,** Faculty, Health Visitor Training School, for their excellent support in completing this project.

All the support staff of NIE for their pleasing attitude and support to the MAE scholars.

All the respondents who spared their valuable time graciously for the project.

I dedicate this dissertation work to the young mothers who not only left their families and children but also left valuable vital evidence and clues for preventing the occurrence of maternal deaths.

Date: 30th June, 2010

Dr.K.Kolandaswamy

TABLE OF CONTENTS

Section 1: Dissertation

Maternal mortality in Tamil Nadu during 2001-10: Varied progress in reducing maternal mortality at the health district level and preventable causes remain unchanged

Abstract

Introduction

India is one of the six countries contributing to 25% of the maternal deaths occurring globally. Within India, Tamil Nadu has the second lowest maternal mortality ratio (MMR per 1,00,000 live births). We conducted descriptive analysis of maternal death surveillance data and ecological analysis for factors responsible for maternal deaths.

Methods

We abstracted data from the maternal death case investigation tool (2009), line-listing (2004-10) and health services reports. We analysed time-trends during 2001-10. We developed MMR areas maps for health unit districts (HUD) for 2008-10. We classified the HUDs into four categories using State MMR of 79 as the mid-point. We calculated MMR by selected socio-demographic and maternal factors using estimated live births as denominators for 2009-10. We calculated distribution (%) of causes and MMR by causes for 2008-10. We abstracted the ecological data of birth rate, institutional deliveries, female literacy, higher birth order and presence of medical college from administrative reports, district and national surveys. We used Poisson regression model for assessing the relationship between MMR and the ecological variables.

Results

During 2001-10, the State MMR declined (χ^2 trend=0.000; p <0.001), however, in 13 of 42 HUDs, MMR remained static. HUDs reporting MMR >120 increased from two in 2009 to seven in 2010. MMR was higher among rural than urban areas (36 vs. 97) and mothers of scheduled tribes and caste had high MMR than from other communities (147 vs. 70). The major causes of maternal deaths were haemorrhage (26%) and hypertension (17%). Higher order births and institutional deliveries were correlated with declining MMR for 2002, 2006 and 2010. Higher birth rate in 2002 and presence of a medical college in 2010 were independently correlated with declining MMR.

Conclusions

We concluded that (1) MMR was static at the HUDs' level (2) hypertension and haemorrhage were still the major preventable causes (3) socio-economically disadvantaged mothers had high MMR (4) institutional births and presence of a medical college were independently associated with declining MMR. In order to reduce MMR at the district level, we recommended to (1) provide hospitalized care to mothers with pregnancy disorders (2) review maternal benefit schemes meant for poor community (3) strengthen the emergency obstetric care and appropriate referral system.

Maternal mortality in Tamil Nadu during 2001-10: Varied progress in reducing maternal mortality at the health district level and preventable causes remain unchanged

Introduction

Maternal mortality represents the most sensitive and key indicator of women's health and status in a society. Recent estimates indicate that 342,900 deaths occurred globally during 2008[1]. More than 50% of these deaths occur in six countries including India[2].

United Nation's Millennium Development Goal 5 aims to reduce Maternal Mortality Ratio (MMR) by three quarters from 1990 to 2015[3]. Though the estimates indicate overall decline in the MMR by 1.3 percent per year in the recent decades, MMR is of concern to both developed and more so in developing countries[2,3]. Further, recent global level analysis indicates that major ecological determinants include Total Fertility Rate (TFR), income per head, maternal educational attainment and skilled attendant at birth[1].

In 2006, India reported a MMR of 254 per 100,000 live births or 85,000 maternal deaths per year (25% of the global burden)[4]. India's National Rural Health Mission's (NRHM) primary focus is to reduce MMR and prioritizing the resource allocation[5].

Major interventions to avert maternal deaths include (1) provision of community-based maternity services (2) Emergency Obstetric and New Born Care services (EmONC). However, within India wide disparity exists in terms of reducing MMR and implementation of the interventions.

Tamil Nadu ranks second in MMR among the major Indian states. In 2009-10, Tamil Nadu reported 926 maternal deaths (amounting to a MMR of 85 per 100,000 live births)[6].Tamil Nadu achieved the national goal of reducing the MMR to less than 100 by 2012 well ahead of

other states. However, this MMR as compared to South East Asian nations such as Sri Lanka(30 in 2008) and Malaysia (42 in 2008) is still higher[1].

Tamil Nadu, established Comprehensive EmONC centres (CEmONC) and Basic EmONC centres (BEmONC) in 2004 and 2006 respectively. Further, to understand the causes of maternal deaths and monitor the health system functioning, the Government of Tamil Nadu introduced the maternal death investigation system in 2004. The purpose was to capture every evidence on the circumstances which led to the death of the mother and take immediate actions. As a result of these interventions, MMR in Tamil Nadu declined from 134 in 2001-03 to 111 in 2004-06[4,7].

However, despite these interventions, maternal deaths do occur due to failure to access quality emergency obstetric care and non-medical causes such as care seeking behaviour, timely availability of transport and delivery of services in the EOC facilities. Through an evaluation study, we recently identified that the functioning of EmONC services were not satisfactory at a district level[8]. Hence, in the context of the achievements made by Tamil Nadu and renewed efforts to further reduce MMR, we need to understand the medical and non- medical causes and descriptive epidemiology of maternal deaths. The valuable data collected through maternal death case investigation tool over the years if fully analyzed, will provide useful feedback to improve the existing system. Further, at the State level, ecological factors associated with MMR were not available in the published literature. Such ecological studies could bring in wealth of information towards formulating new strategies[9-12].

Hence, we conducted a study to (1) describe the maternal deaths and causes by time, place and person, (2) identify ecological factors responsible for maternal deaths, (3) generate hypotheses and (4) recommend appropriate interventions.

Methods

Study design

We conducted descriptive and ecological studies on maternal deaths.

Study population

For the descriptive analysis, we included all the maternal deaths reported and investigated through the maternal deaths investigation tool during 2008-2009. We included all the maternal deaths that were line-listed during 2004-10. For the ecological analysis, we included all the maternal deaths reported during 2001-10.

Data collection

Descriptive study

We used abstraction forms to extract data from (1) maternal and child health (MCH) reporting forms 2000-10 (2) maternal death investigation case sheets 2008-09 (3) family welfare reports 2000-10. From the maternal death investigation tool, we abstracted information on socio-economic characteristics, availability of health facilities, services, transport, awareness and birth preparedness of family, treatment in the referral institutions for the problem, which led to the death of the mother.

Ecological study

We collected ecological data from (1) administrative reports (2) planning commission (3) Statistical reports (4) District Level Household Survey (DLHS) (4) National Family Health Survey (NFHS). From these sources, we abstracted data at the level of district, on overall literacy status, maternal literacy level, institutional delivery, higher order births, gross

domestic product, birth rate, caesarean section rate, human development index and gender development index.

Operational definitions

We operationally defined the variables related to maternal mortality on the basis of WHO guidelines[13].

Maternal death: The death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes.

Maternal Mortality Ratio (MMR): The Maternal Mortality Ratio is the number of maternal deaths per 100,000 live births per year.

Direct obstetric deaths:

Maternal deaths resulting from obstetric complications of the pregnant state (pregnancy, labour, and the puerperium), from interventions, omissions or incorrect treatment, or from a chain of events resulting from any of the above.

Indirect obstetric deaths:

Maternal deaths resulting from previous existing disease or disease that developed during pregnancy and that was not due to direct obstetric causes but was aggravated by the physiological effects of pregnancy.

Data analysis

Descriptive study

We analysed the data on maternal deaths by time, place and person. With reference to time, we plotted the MMR by time on a line graph and used chi-square test for assessment of linear trend.

We calculated MMR by person data of socio-demographic variables and maternal data using estimated live births as the denominators (2001 census). We computed percent distribution of causes and cause-specific MMR.

We calculated MMR for each of the 42 HUDs and Chennai city. We considered the State MMR (79) in 2008-09 as the mid-point for classification and categorized all the HUDs as very low (<40), low (41-80), high (81-120) and very high (121+). We created MMR area maps for the district level for 2008-10.

Ecological analysis

We performed Poisson regression analysis to identify the factors associated with quantum of maternal deaths in districts. Our approach to regression was Generalized Linear Model with log link[14].We used actual number of maternal deaths in a district as dependent variable. Since the denominators (live births) of this variable for each district varied, we incorporated offset variable of total number of live births into the model. The scale parameter was made as one. We selected the independent variables (explainable) for modelling, based on their importance and choose them on the basis of correlations. The independent variables considered were birth rate, GDI, female literacy, higher birth order and institutional births. Data sets for 2001-02, 2005-06 and 2009-10 were selected to look for the pattern over different time points. Availability of medical colleges was taken only for the year 2009-10, since maximum number of colleges were established during this period and the catchment areas were largely

confined to the corresponding districts. Best fitting model was chosen based on the Akaike's Information Criteria (minimum) and the ratio of deviance value to degrees of freedom (ratio closer to 1).We performed logarithmic transformation for indices and Arc Sine transformation for proportions.

Human subject protection

We obtained approval of the Institutional ethics committee of the National Institute of Epidemiology, Chennai. We collected secondary data from the health services and refrained from using any identifiers.

Results

Descriptive study

Maternal mortality in Tamil Nadu had been declining since 2001 (χ^2 trend $p<0.001$). However, at the HUD level, 13 of 43 HUDs (including Chennai city) the MMR remained static throughout this period (Annexure-1).

MMR was almost three times higher in rural than urban areas (36 vs. 97) during 2008-09. Chennai reported the lowest (29) and Dindigul HUD recorded the highest MMR of 154. Very high MMR (> 120) districts increased from two in 2008-09 to seven in 2009-10 (Figure 2) (Annexure 2).

During the year 2009-10, MMR among the socially disadvantageous groups, higher maternal age, and third gravida and above were high (Table-1). Proportion of maternal mortality among illiterate mothers was 19% and the husbands of 36% of the mothers who died were agricultural labourers and 27% were daily wage labourers.

During the year 2008-09, 70% of maternal deaths occurred during postnatal, 11% during intra natal and 19% during antenatal period and these proportions remained the same during

2004-10. Maternal mortality among mothers who delivered normally, declined from 80% in 2004-05 to 65% in 2009-10 and caesarean rate among the mothers died had gone up to 35% from 18% in 2004-05 (Annexure-8).

During 2008-09, 21% of the births were still births, 25% of the mothers had previous bad obstetric history, and 42% of the women had risk factors and problems during their current pregnancies. In 6.6% of the mothers the time interval between the onset of labour pain and delivery was more than 18 hours.

In 2008-09, 31.2% of the deaths occurred in government medical college hospitals, 23% in transit, 17% in private hospitals, 11.8% in district headquarters hospitals, 8.8% at home, 1.8% at urban health posts, 1% at sub- district hospitals, 0.5% at PHCs, 0.1% at HSCs and 4.8% in other institutions.

Home as the place of delivery of the deceased mothers declined from 20.6% in 2004-05 to 7.3% in 2009-10 and PHC as place of delivery increased from 4.7% to 18.4% over the last six years (Annexure-6).

Proportion of maternal deaths occurring during transit, at government medical college hospitals, at private hospitals, at district headquarters hospitals remained constant during 2004-10. Maternal deaths at home declined from 20% in 2004-05 to 9.7% in 2009-10 (Annexure-7).

Maternal deaths by Primary Health Centre (PHCs) indicate that majority of the PHCs reported two deaths (n=125). We also identified that some of the PHCs reported more than two maternal deaths and the maximum number of eight deaths were reported by two PHCs.

Medical causes of maternal deaths, 2004-10

Direct obstetric causes of maternal deaths

The top-most direct obstetric cause of maternal deaths in 2008-09 was that of haemorrhage (26%, n=656). Of these, 24% was post-partum and 2% was ante-partum haemorrhage. In fact, MMR attributable to haemorrhage declined from 30 in 2006-07 to 21 in 2009-10. However, MMR due to hypertensive disorders of pregnancy has increased from 10 to 13 for the same period. The other major causes in 2008-09 included eclampsia (16.8%), pulmonary embolism (8.4%), Amniotic fluid embolism (5.6%), sepsis (5.5%), Cortical Vein Thrombosis (4.7%), complications of sterilisation surgeries (such as caesarean with tubectomy, medical termination of pregnancy with tubectomy and puerperal sterilisation) (3.5%), obstructed labour/ruptured uterus (2.8%) and complications of caesarean sections (2.2%). Proportion of deaths due to direct obstetric causes over the years remained constant. (Annexure-3 and 9).

Indirect obstetric causes

Indirect obstetric causes of maternal deaths in 2008-09 were heart diseases complicating pregnancy (7.6%), Jaundice (3.7%), infectious diseases and anaemia complicating pregnancy (2.4%). We identified that 158 deaths (19%) were due to indirect obstetric causes (Annexure 3 and 10).

Non-obstetric causes

Small proportion of (2.3%, n=19) maternal deaths were misclassified as maternal deaths during 2008-09 (Annexure-3).

Non-medical factors associated with maternal deaths

During 2008-09, only 8% (n=52) of the mothers died in the health facility in which they got admitted. Of the 670 deaths for which referral data available, 38% were referred to one institution, 37% were referred for the second time to another institution and 14% visited three institutions and 3% visited four different institutions before death. According to the reporting officers, lack of hospital supplies, lack of availability of blood, non-availability of specialists, delay in treatment initiation, lack of preparedness and awareness of pregnancy complications, reaching a wrong referral institution, delay in getting the transport from one institution to the other were mentioned as perceived contributing factors for the maternal deaths.

Ecological study

The multivariate analysis was limited to 2001-02, 2005-06 and 2009-10, since all the data elements were not available for all the time-points (Table 2). Information on the presence a medical college was used for 2009-10. We observed that the declining higher order of births, increasing institutional deliveries and availability of caesarean sections were associated with the overall fall in MMR (Figure-3).

In 2001-02 higher order births (in Arc Sine) was positively associated with maternal mortality. High birth rate was negatively associated with MMR in 2001-02. Higher birth rate was not associated with maternal mortality in 2005-2006. Institutional births became a stronger indicator for lowering MMR. Also higher order of birth is a detrimental factor for reducing MMR.

Presence of medical college in a district was found to be associated with reduction in MMR. The contribution of other variables (institutional birth, higher order birth) remained the same as above.

Discussion

Tamil Nadu ranked second in the MMR and implemented interventions at the field level to reduce maternal deaths in the State. However, in order to reduce it further, we reviewed the data on maternal deaths collected through routine system and specific surveillance mechanism. We analysed the data to understand the epidemiology of maternal deaths and ecological determinants of maternal mortality ratio in Tamil Nadu. Our major findings of immediate concern to policy makers and programme managers included (1) no decline in the MMR in few sub-districts (2) no change in the major preventable causes of maternal deaths such as haemorrhage and hypertensive disorders (3) high MMR among socio-economically disadvantaged sections. However, a noteworthy finding from the ecological study was that of independent correlation of presence of medical college and speciality centres with the reduction of MMR.

While overall decline in MMR is consistently been reported through various reports and surveys[4,6,7,15], may be this is the first time, we identified that the same was not true in 13 Health Unit Districts. The overall decline had been masking these variations at the district and sub-district levels. Hence, the State needs to focus efforts in these areas to further reduce the MMR. In fact, Chinese investigators have reported such substantial variation within a province[9].

The peak in MMR that was observed in 2001 could be an artefact and needs to be interpreted in the context of how Tamil Nadu introduced and strengthened the maternal mortality reporting system. Tamil Nadu initiated identification and compulsory reporting of maternal deaths in 1994. It was mandated that each and every maternal death be reported by the village health nurse and the medical officers[15]. Multiple reporting and line-listing of the maternal deaths by health unit districts and encouragement from the administration to the village health nurses, the reporting improved substantially from 1994 and the maximum number of

deaths reported were in the year 2001. Hence the peak indicated that the maternal mortality surveillance system was able to capture all the maternal deaths from the year 2001 onwards. Since every death is audited and classified as maternal death, the reports could be considered as reliable.

We observed no changes in the major causes of the maternal deaths over the years. Haemorrhage was the major cause of maternal deaths. However, cause specific mortality suggested a decline in MMR due haemorrhage. This may be due to the thrust on Active Management of Third Stage of Labour (AMSTL) initiated and implemented in Tamil Nadu since 2007[16]. Even at the global and regional level, these causes remain significant contributors[1,17].

The last important observation of high MMR among socio-economically disadvantaged sections needs further carefully planned studies. Tamil Nadu initiated pioneering projects of maternity benefit schemes[18] and free emergency maternity ambulance services[19]. Despite these interventions, we identified that deaths due to prolonged labour still reported one of the medical causes of maternal death. Further the unchanging pattern of MMR among socially disadvantageous groups needs immediate attention. Since the national government actively considering adaptation of Tamil Nadu's maternity benefit scheme, we need indepth studies to understand the effectiveness of such schemes in reducing MMR.

The ecological analysis suggested that the provision of medical college was negatively associated with the MMR. This needs to be interpreted in the context of ecological nature of the analysis. However, the association between increased institutional deliveries and reduced MMR is consistently seen in many reports and could be considered as a direct result of interventions to promote institutional deliveries in Tamil Nadu[15].

Further our finding of inverse relationship between MMR and birth rate during the year 2001-02, needs to be interpreted in the context of several factors. Firstly, the emergence of gestational diabetes mellitus and increasing proportion of high birth weight babies. Secondly, the artefact that we observed in the reporting system during that period could have also contributed to such association which was not observed in the other two time-points. Lastly we may attribute to the falling denominators (decrease in birth rate) due to thrust on family planning services without adequate EmONC service during the same point of time.

Some findings need further in-depth studies. Firstly, maternal deaths among women who underwent sterilisation surgeries and caesarean sections we may need detailed medical audits of such deaths. Secondly, high level of second and third referrals from one facility to the other, deaths during transit and higher proportion of maternal deaths in medical college hospitals indicate that CEmONC services were either not available in other hospitals or women in emergency were taken to the wrong place without ascertaining the availability of services. We observed similar findings in an evaluation study of CEmONC services in one district[8]. It may be worthwhile conducting detailed study in those HUDs where we did not observe any decline till date.

Thirdly, a focused study is needed to explain unchanging proportion of preventable causes of maternal deaths despite the expansion of CEmONC services and higher proportion of still births among the mothers died.

Our study may have limitations that could be inherently present in secondary data analysis. We analysed maternal deaths obtained through multiple reporting systems. Since maternal mortality surveillance reached a mature state in 2001, the reported deaths would be close to the actual number of deaths[15]. Further, we used multiple data sources to complement the information. For instance, for cause of death, we used case investigation forms completed by

the district chief medical officer. We used information from line-listing system to supplement whenever, information was incomplete in the case-investigation sheet. Hence, we consider that the conclusions could be broadly reliable.

On the basis of the descriptive and ecological analysis of maternal deaths in Tamil Nadu, we concluded that (1) as compared to the overall decline observed at the State level, there was no decline at the smaller administrative areas (2) the distribution of maternal deaths was not uniform across the State and deaths were more in certain sub-districts and rural areas (3) while MMR attributable to haemorrhage declined marginally, the MMR due to hypertensive disorders of pregnancy increased marginally (4) MMR was high among socio-economically disadvantaged groups, women with risk factors and women with higher order of births (5) high risk mothers with bad obstetric history and with some problems with current pregnancies experienced high mortality (6) the provision of referral and speciality centres contributed to the reduction of MMR.

Based on our findings, we recommended both short-term and long-term measures. The short-term measures included (1) family planning services should focus on reducing higher order of births (HOB) particularly in districts with high level of HOB (2) Women with previous bad obstetric history and risk factors are to be identified and admitted early in the CEmONC centres (3) focus on cause specific MMR to reduce maternal deaths (haemorrhage and hypertensive disorders of pregnancy).

As a long-term measure, we recommended (1) formulate policy to increase the allocation of resources and capacity building of healthcare providers in PHCs reporting more deaths and HUDs not showing declining trend (2) improve the CEmONC centres adequately, to avoid referrals (3) develop special programmes such as Pregnancy Induced Hypertensive Disorders Control Programme and adequate focus on availability of blood and active management of

third stage of labour (4) develop case studies on maternal deaths to educate health care providers and the community to prevent such deaths. Further, the hypotheses generated through this study merits in-depth studies.

References

1. SY, Wang M, Makela SM, Lopez AD, Lozano R, Murray CJ. Maternal mortality for 181 countries, 1980-2008: a systematic analysis of progress towards Millennium development Goal 5. Lancet. 2010;375(9726):1609-23.

2.Bhutta ZA, Chopra M, Axelson H, Berman P, Boerma T, Bryce J *et al*. Countdown to 2015 decade report (2000-10): taking stock of maternal, newborn, and child survival. Lancet. 2010;375(9730):2032-44.

3. United Nations. The Millennium Development Goals Report 2010. New York: United Nations, 2010.

4. Government of India. Maternal Mortality in India : 2004-2006: Trends, causes and Risk factors. New Delhi: Registrar General of India; April, 2009.

5. National Rural Health Mission, Government of India. Mission Document (2005-2012): New Delhi 2005

6. Government of Tamil Nadu. Maternal and Child Health Report 2010. Chennai: Directorate of Public Health and Preventive Medicine, Government of Tamil Nadu; 2010.

7. Government of India. Maternal Mortality in India : 1997-2003: Trends, causes and Risk factors. New Delhi; Registrar General of India; October, 2006.

8. Kolanda Swamy. K. Evaluation of the emergency obstetric and newborn care services in Thiruvallur district, Tamil Nadu, India, 2009. Bound volume containing field projects; National Institute of Epidemiology, Chennai; December,2009.

9. J Li, c Luo, R Deng, P Jacoby, N de klerk. Maternal mortality in Yunnan, China : recent trends and associated factors. British journal of Obstetrics and Gynaecology, May 2007.

10. Nancy L Sloan, Beverly Winikolf, and Fariyal F Fikree. An ecologic analysis of maternal mortality ratios. Studies in family Planning 2001; 32 (4): 353-355.

11.Shiffman J. ' Can poor countries surmount high maternal mortality? ' Studies in Family Planning 2000;31(4): 274-289.

12. Rice J. Material consumption and social well-being within the periphery of the world economy: An ecological analysis of maternal mortality. Social Science Research 2008;37:1292-1309

13.WHO.Reduction of maternal mortality: A joint WHO/UNFPA/UNICEF/World Bank statement.Geneva: World Health Organisation;1999.

14.George W Snedecor, William G Cochran. Statistical methods. New Delhi; Oxford and IBH publishing company; 1967 Sixth edition page 327-330.

15. WHO.Safer pregnancy in Tamil Nadu: from vision to reality. New Delhi; World Health Organisation,2009.

16. Department of Public Health and Preventive Medicine. Active Management of Third Stage of Labour: Guidelines. Chennai: DPH and PM, 2007

17. WHO and UNICEF. Countdown to 2015: Decade Report (2000-2010) with country profiles: Taking stock of maternal, newborn and child survival. Geneva: World Health organisation and UNICEF; 2010.

18. Government of Tamil Nadu. Dr.Muthulakshmi Reddy Maternity Benefit Scheme. Chennai: Health and Family Welfare Department, 2006.

19. Government of Tamil Nadu. Emergency Management Research Institute: Operational guidelines. Chennai: Health and Family Welfare Department, 2008.

Table 1: Maternal mortality ratio (MMR) (per 100,000 live births) by selected characteristics, Tamil Nadu, 2009-10

Characteristics		# maternal deaths	# estimated live births*	MMR
Age (years)	< 20	27	53,181	51
	20-24	383	5,43,753	70
	25-29	343	3,54,905	97
	30-34	105	99,851	105
	35-39	50	28,219	177
	40+	18	5,427	332
Community	Scheduled tribe/caste	320	2,17,067	147
	Others	606	8,68,269	70
Religion	Hindu	864	9,56,181	90
	Others	62	1,29,155	48
Residence† (2008-09)	Rural	753	7,74,390	97
	Urban	116	3,24,035	36
Gravida	Primi	374	529,644	71
	Second	294	402,600	73
	Third	140	115,046	122
	Fourth+	118	37,986	311

* Calculated on the basis of 2001 Census

† Data on residential status was on the basis of 2008-09 data

Table 1: Predictors of maternal deaths by generalized linear model (Poisson), Tamil Nadu, 2002, 2006 and 2010

Model[1]	Independent variables	Coefficient (β)	(95% confidence interval)	p value
Year: 2001-02	Constant	-2.85	(-4.609, -1.091)	0.001
	Birth rate[2]	-1.031	(-1.609,-0.453)	0.000
	Higher order birth[3]	0.786	(0.415,1.158)	0.000
	Institutional deliveries[3]	-0.233	(-0.442, -0.025)	0.028
Year: 2005-06	Constant	-5.557	(-5.948, -5.166)	0.000
	Higher order birth[2]	0.912	(0.483,1.340)	0.000
	Institutional deliveries[3]	-0.644	(-0.987, -0.300)	0.000
Year: 2009-10	Constant	-5.316	(-7.041, -3.590)	0.000
	Presence of medical college in the district	-0.272	(-0.408, -0.135)	0.000
	Higher order birth[2]	0.732	(0.205, 1.260)	0.007
	Institutional deliveries[3]	-0.644	(-1.903, 0.615)	0.316

[1] *Dependent variable:* Maternal deaths; *Offset variable:* Transformed to logarithmic values of Total births
[2]Transformed to logarithmic values
[3] Transformed to ArcSine values

Figure.1: Time trends in maternal mortality ratio, Tamil Nadu, India, 1999-2010

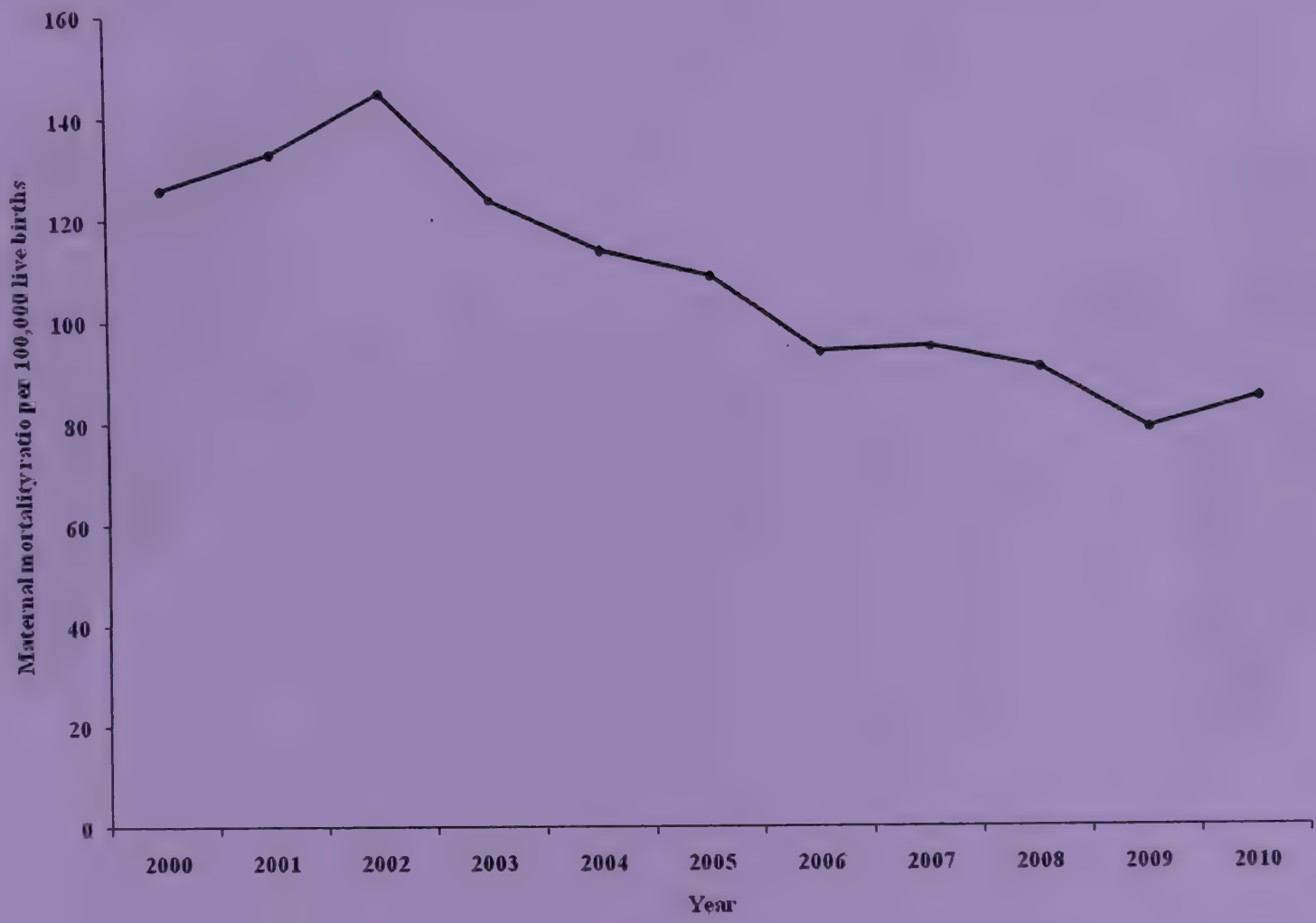
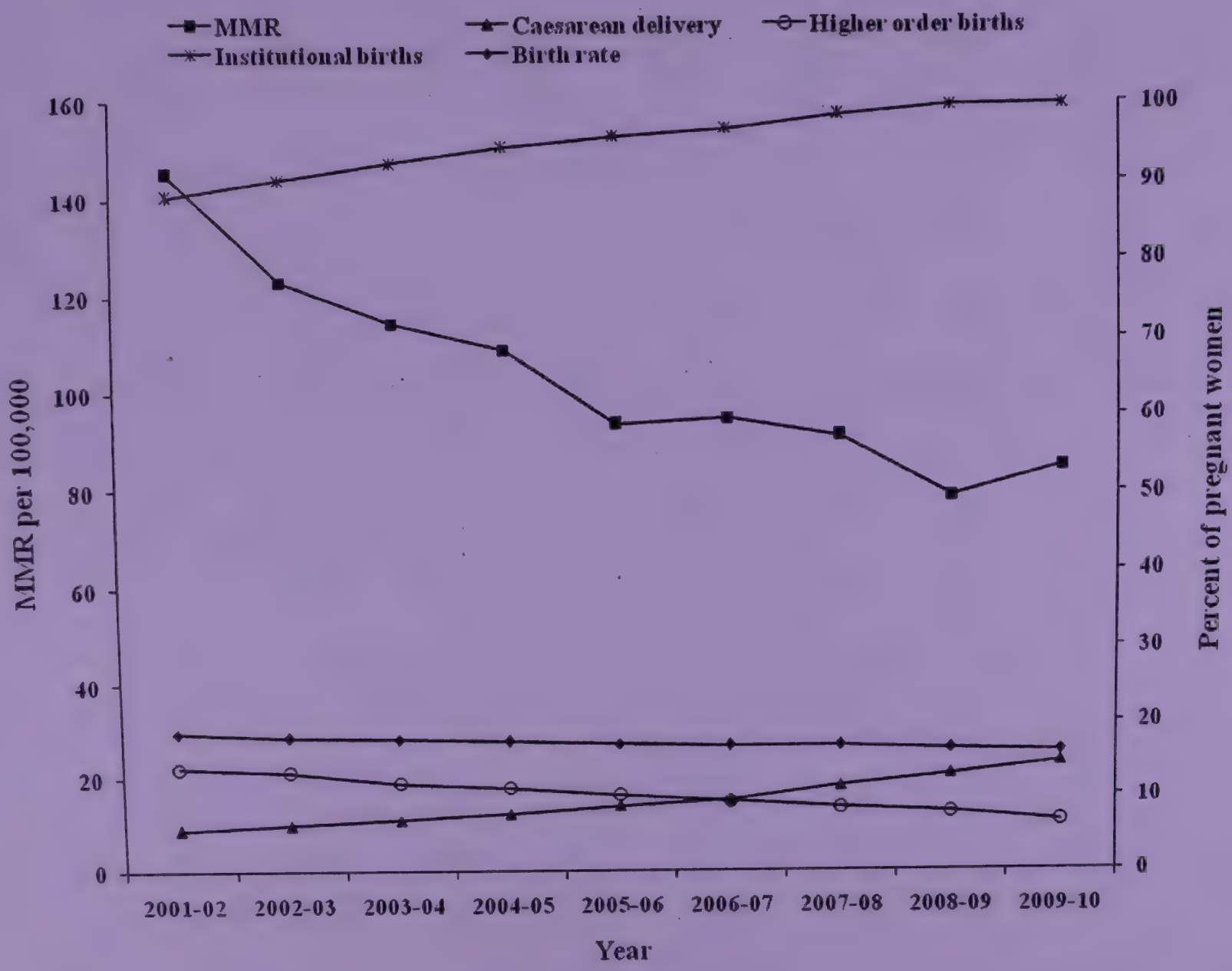


Figure 2: Geographical distribution of maternal mortality ratio (per 100,000 live births) by health unit districts in Tamil Nadu, India, 2008-10

Figure 3: Time-trends in maternal mortality ratio (MMR) (per 100,000 live births) and percent women with selected characteristics, Tamil Nadu, 2002-10



Annexure.1: Time trends in Maternal Mortality Ratio in Tamil Nadu, India, 1999-2009

Health District	Unit	Maternal Mortality Ratio										Chisquare test
		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	P
Cuddalore		84	138	142	97	109	88	62	110	91	62	76	0.003
Villuppuram		117	123	158	179	144	88	107	73	119	77	87	0.001
Kallakurichi		133	153	144	163	109	109	106	150	123	98	137	0.195
Thanjavur		126	101	158	135	118	103	89	102	85	62	71	0.000
Nagappattinam		183	176	142	190	112	293	93	139	95	66	84	0.000
Thiruvarur		142	155	164	152	95	110	52	73	98	60	106	0.000
Pudukkottai		116	101	197	54	126	106	71	77	118	121	93	0.323
Aranthangi		99	158	129	115	191	118	134	63	144	117	69	0.205
Tiruchirappalli		139	88	162	110	129	150	146	120	132	117	100	0.533
Perambalur		209	182	204	219	115	188	122	82	142	108	109	0.000
Karur		190	197	198	155	189	91	138	126	108	121	135	0.003

Health District	Unit	Maternal Mortality Ratio											Chisquare test
		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	P
Dindigul		153	255	124	170	180	133	145	193	123	105	154	0.047
Palani		150	179	137	109	120	112	125	158	112	124	122	0.284
Madurai		87	125	122	115	104	111	105	98	112	91	124	0.894
Theni		121	192	215	170	144	139	80	30	94	68	84	0.000
Sivaganga		101	54	114	100	78	119	71	75	81	85	129	0.683
Ramanathapuram		66	108	96	149	106	130	118	83	99	100	93	0.934
Paramakudi		201	251	109	202	196	272	53	159	117	95	117	0.002
Virudunagar		158	148	167	98	130	105	83	126	51	187	117	0.215
Sivakasi		132	162	144	161	167	156	142	115	127	133	131	0.317
Tuticorin		196	122	241	117	176	149	140	146	84	123	143	0.024
Koilpatti		208	205	266	193	151	110	183	127	95	95	119	0.000

Health District	Unit	Maternal Mortality Ratio										Chisquare test
		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	P
Tirunelveli		220	141	209	211	122	110	168	193	43	120	115	0.000
Sankarankoil		105	132	156	134	124	150	66	72	81	55	98	0.001
Nagercoil		110	97	107	50	60	127	82	75	36	67	42	0.001
Kancheepuram		116	124	159	123	165	152	92	132	75	51	67	0.001
Saidapet		110	84	78	93	71	57	80	69	74	49	55	0.003
Thiruvallur		144	79	157	132	115	79	56	70	85	63	77	0.000
Poonamallee		81	117	75	97	58	82	71	108	24	69	34	0.027
Thiruvannamalai		129	99	125	133	97	80	89	82	114	79	70	0.012
Cheyyar		34	160	238	179	82	76	138	114	104	113	108	0.295
Vellore		172	189	211	210	192	107	126	88	95	81	45	0.000
Thirupathur		99	118	207	196	183	113	107	113	80	48	60	0.000

Health District	Unit	Maternal Mortality Ratio										Chisquare test
		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	P
Dharmapuri		161	146	161	106	136	104	124	104	126	91	79	0.001
Krishnagiri		151	162	146	153	150	137	139	101	114	109	93	0.001
Salem		140	133	143	111	128	128	102	90	90	63	91	0.000
Namakkal		124	166	225	111	112	136	74	93	104	95	149	0.014
Erode		144	121	145	113	69	116	110	53	97	112	42	0.000
Dharapuram		88	137	122	104	99	90	84	77	119	129	58	0.318
Coimbatore		88	95	87	67	78	54	40	51	60	54	46	0.000
Thiruppur		77	113	88	70	88	59	70	102	87	55	68	0.190
Udhagamandalam		204	172	154	146	172	126	136	85	170	49	117	0.005
Chennai		80	99	81	18	21	13	20	43	22	19	29	0.000
Tamil Nadu		126	133	145	123	114	109	94	95	91	79	85	0.000

Annexure.2: Classification of Health Unit Districts based on Maternal Mortality Ratio, Tamil Nadu, India, 2010

Very low MMR HUDs	Low MMR Health Unit Districts		High MMR Health Unit Districts		Very High MMR HUDs
Chennai (29)	Erode (42)	Thiruppur (68)	Nagappattinam (84)	Tituchy (100)	Dindigul(154)
Poonamallee(34)	Nagercoil (42)	Aranthangi (69)	Theni (84)	Thiruvarur (106)	Namakkal(149)
	Vellore(45)	Thiruvannamalai (70)	Villuppuram (87)	Cheyyar(108)	Tuticorin(143)
	Coimbatore (46)	Thanjavur (71)	Dharapuram(88)	Perambalur(109)	Kallakurichi (137)
	Saidapet (55)	Cuddalore (76)	Salem(91)	Tirunelveli(115)	Karur(135)
	Thiruppathur (60)	Thiruvallur (77)	Pudukkottai(93)	Nilgiris(117)	Sivakasi(131)
	Kancheepuram(67)	Dharmapuri (79)	Ramnad(93)	Paramakkudi(117)	Sivaganga(129)
			Krishnagiri(93)	Virudunagar(117)	Madurai(124)
			Sankarankoil(98)	Koilpatty(118)	Palani(122)

Annexure.3: Proportion of medical causes of maternal deaths from case investigation tool (n=833), Tamil Nadu, India, 2008-2009

Direct causes (78.8% n=658)			**Indirect obstetric causes (18.9% n=158)**		
Cause	**Number**	**Percentage**	**Cause**	**Number**	**Percentage**
Post Partum Haemorrhage(PPH)	198	23.8	Heart diseases complicating pregnancy	63	7.6
Eclampsia	140	16.8	Jaundice	31	3.7
Pulmonary Embolism	70	8.4	Infectious diseases	22	2.6
Amniotic Fluid Embolism	47	5.6	Anaemia complicating pregnancy	20	2.4
Sepsis	46	5.5	Cancer	5	0.6
CVT	39	4.7	Epilepsy	5	0.6
Complications of sterilization	29	3.5	Others	12	1.4
Obstructed labour/ruptured uterus	23	2.8	**Non obstetric causes (2.3% n=19)**		
Surgical complications	18	2.2	Injury	8	1.0
Ante Partum Haemorrhage	15	1.8	Others	11	1.3
Uterine inversion	6	0.7			
Abortion	7	0.8			
Others	18	2.2			

Annexure.4: Maternal deaths due to complications of sterilisations, Tamil Nadu, India, 2004-2009

Name of the district	# Maternal deaths as a complication of sterilisation from 2004-05 to 2008-09	#sterilisation surgeries from 2004-05 to 2009-10	# of maternal deaths per100,000 sterilisations
1.Virudhunagar	12	58210	20.6
2.Vellore	20	112889	17.7
3.The Nilgiris	3	17807	16.8
4.Coimbatore	16	106266	15.1
5.Ramnad	4	32262	12.4
6.Sivagangai	4	33566	11.9
7.salem	11	103751	10.6
8.Theni	4	38177	10.5
9.Erode	8	77899	10.3
10.Thiruvarur	3	29957	10.0
11.Namakkal	4	41291	9.7
12.Madurai	8	86101	9.3
13.Dharmapuri	5	54548	9.2
14.Karur	2	22435	8.9
15.Krishnagiri	4	45442	8.8

16.Thanjavur	5	68790	7.3
17.Tirunelveli	5	76380	6.5
18.Kanyakumari	3	51599	5.8
19.Thiruvallur	3	55189	5.4
20.Kancheepuram	4	75241	5.3
21.Chennai	10	293175	4.7
22.Tuticorin	2	43376	4.6
23.Thiruvannamalai	3	68032	4.4
24.Villuppuram	3	68759	4.4
25.Nagappattinam	1	25374	3.9
26.Tiruchy	2	54823	3.6
27.Dindigul	2	60829	3.3
28.Cuddalore	1	67482	1.5
29.Perambalur	0	23384	0
30.Pudukkottai	0	36202	0
Tamil Nadu	152	1850036	8.2

Annexure. 5: Socio demographic characteristics of maternal deaths from line listing in Tamil Nadu, India, 2004-2010

Characteristics	2004-05 (n=1034)	2005-06 (n=1045)	2006-07 (n=1054)	2007-08 (n=1023)	2008-09 (n=869)	2009-10 (n=926)
Religion						
Hindu	93.8	91.7	92.7	92.6	91.8	93.3
Muslim	2.6	3.9	4.0	4.9	4.6	3.1
Christian	3.7	4.4	3.3	2.5	3.5	3.6
Others	0	0	0	0	0	0
Community						
SC	30.6	31.6	32.9	32.1	27.3	32.0
ST	3.1	2.4	3.4	3.7	4.1	2.6
Others	66.3	66.0	63.7	64.2	68.6	65.4

Characteristics	2004-05 (n=1034)	2005-06 (n=1045)	2006-07 (n=1054)	2007-08 (n=1023)	2008-09 (n=869)	2009-10 (n=926)
Age at death						
<20	4.3	4.8	3.8	3.6	4.9	2.9
20-24	36.9	36.3	38.4	40.3	40.8	41.4
25-29	36.6	35.5	36.9	37.1	35.3	37.0
30-34	14.2	13.5	12.8	11.6	12.2	11.3
35-39	7.5	8.6	7.1	6.3	5.2	5.4
40 and above	1.5	1.4	0.9	1.2	1.7	2.0
Order of birth						
Primigravida	37.8	37.8	40	39	39.9	40.4
2nd gravid	26.8	25.7	28	32.1	28.8	31.7
3rd Gravida	16.3	17.4	15.3	14.9	17.5	15.1
4 and above	19.1	19.1	16.7	14	13.8	12.7

Annexure.6: Place of delivery of maternal deaths from line listing in Tamil Nadu, India, 2010

Place of delivery	2004-05 (n=1034)	2005-06 (n=1045)	2006-07 (n=1054)	2007-08 (n=1023)	2008-09 (n=869)	2009-10 (n=926)
Home	20.6	16.5	16.1	11.1	8.9	7.3
Transit	0.6	1.7	1.1	1.2	0.7	1.0
Health Sub Centre	1.8	1.8	1.8	2.4	0.9	0.7
Primary Health Centre	4.7	4.8	5.3	8.3	15.8	18.4
Health Post / Maternity centre	2.6	1.4	0.8	0.7	1.2	3.2
Govt. Hospital	21.0	17.4	17.8	17.7	14.3	13.1
District Headquarters Hospital	3.9	5.5	6.4	5.5	4.5	6.4
Govt. Medical College Hospital	18.8	22.2	21.5	24.1	24.7	25.1
Private Hospital	25.9	28.6	28.9	29.1	28.8	24.3
ESI Hospital	0.4	0	0.3	0	0	0
Others	0	0	0	0	0.2	0.6

Annexure.7: Place of death of maternal deaths from line listing in Tamil Nadu, India, 2010

Place of death	2004-05 (n=1034)	2005-06 (n=1045)	2006-07 (n=1054)	2007-08 (n=1023)	2008-09 (n=869)	2009-10 (n=926)
Home	20.4	15.9	15.4	10.8	9.7	9.7
Transit	16.1	17.9	18.9	19.6	16.9	16.2
Health Sub Centre	0	0.4	0.2	0.3	0.2	0
Primary Health Centre	0.9	0.9	0.4	0.8	0.9	1.3
Health Post / Maternity centre	0.3	0.7	0.5	0.8	2.9	3.6
Govt. Hospital	7.6	6	4.9	4.8	5.7	5.8
District Headquarters Hospital	7.1	8.7	8.9	8.1	7.3	6.7
Govt. Medical College Hospital	27.1	29.2	30.5	35.3	36.2	38.7
Private Hospital	20.4	20.2	20.1	19.6	20.1	18.1
ESI Hospital	0	0	0.1	0	0	0
Others	0.1	0.1	0.1	0	0	0

Annexure.8 : Medical characteristics of maternal deaths in Tamil Nadu, India, 2010

Characteristics	2004-05 (n=1034)	2005-06 (n=1045)	2006-07 (n=1054)	2007-08 (n=1023)	2008-09 (n=869)	2009-10 (n=926)
Type of delivery						
Normal	80.4	75.8	76.0	70.4	58.6	65.3
Assisted	1.3	2.3	2.0	4.1	6.6	3.3
Caesarean	18.3	21.9	22.0	25.5	34.8	31.4
Period of death						
Antenatal	27.4	22.4	23.2	22.6	18.9	21.2
Intranatal	6.2	4.9	5.3	5.5	10.5	4.2
Postnatal	66.4	72.7	71.5	71.9	70.6	74.6

Annexure.9: Proportion of direct medical causes of maternal deaths from line listing, Tamil Nadu, India, 2008-2009

Cause of Death	2004-05 (n=1034)	2005-06 (n=1045)	2006-07 (n=1054)	2007-08 (n=1023)	2008-09 (n=869)	2009-10 (n=926)
Post Partum Haemorrhage(PPH)	23.9	23.9	28.6	23.9	28.8	21.8
Eclampsia	12.3	10.9	11.1	13.5	14.0	14.7
Pulmonary Embolism	6.1	5.2	3.9	6.9	6.9	6.6
Amniotic fluid embolism	4.6	4.0	3.8	5.8	5.6	6.2
Sepsis	4.7	7.1	6.2	5.2	5.9	5.7
CVT	5.2	4.8	4.5	6.2	5.4	5.7
Complications of sterilization	0.1	0.3	0.0	0.1	0.0	0.1
Obstructed labour/ruptured uterus	3.6	3.0	1.1	1.8	2.5	1.8
Surgical complications	0.9	1.1	0.9	1.6	1.0	1.0
Ante Partum Haemorrhage(APH)	3.7	5.1	3.0	3.3	3.4	3.0
Uterine inversion	0.4	0.4	0.3	0.1	0.3	0.8
Ectopic pregnancy	0.0	0.2	0.2	0.1	0.1	0.1
Abortions	1.5	1.3	1.1	0.9	0.7	1.3

Annexure.10: Proportion of indirect medical causes of maternal deaths from line listing, Tamil Nadu, India, 2004-2010

Cause of death	2004-05 (n=1034)	2005-06 (n=1045)	2006-07 (n=1054)	2007-08 (n=1023)	2008-09 (n=869)	2009-10 (n=926)
Heart diseases complicating pregnancy	7.6	7.8	9.1	7.8	5.6	7.2
Jaundice	2.0	2.4	3.8	3.0	3.7	3.7
Infectious diseases	1.7	2.3	1.5	2.7	1.4	1.0
Anaemia complicating pregnancy	6.3	4.8	4.5	3.4	3.5	3.3
Bronchial Asthma	0.3	0.1	0.1	0.1	0.0	0.4
Cardio respiratory arrest	5.8	8.9	8.8	8.4	8.6	10.2
Others causes (Direct and Indirect)	3.0	4.0	3.6	4.0	2.0	3.7
Non obstetric causes						
Injury	2.6	0.6	1.0	0.2	0.1	1.0
Other non obstetric causes	3.7	1.8	2.9	1.0	0.5	0.7

Annexure.11: Ecological data collection form

District	Year	Mid Year Population	Live Births	Maternal Deaths	Male literacy	Female literacy	Institutional deliveries	Birth weight > 3kg	Higher Order Births	Human Development Index	Gender Development Index	Availability of Medical college

Section 2: Review of literature

Maternal deaths: Surveillance methods, known causes and ecological determinants

Introduction

Maternal mortality is a key indicator of women's health and status, and shows most poignantly the difference between rich and poor, both between countries and within them. Globally, 529,000 mothers die every year from complications of child birth. 99 percent of all of these deaths occur in developing countries. Most of these deaths and disabilities attributable to child birth are avoidable, because the medical solutions are well known[1,2]. In developing countries, one woman in 16 may die of pregnancy related complications compared to one in 2800 in developed countries[3]. However in 2008, a study on maternal mortality for 181 countries, estimated 3,42,900 maternal deaths, down from 5,26,300. The global MMR decreased from 422 in 1980 to 320 in 1990, and was 251 per 100,000 live births in 2008[4]. Each death represents an individual tragedy for the woman, her partner, her children and her family.

In 2000, the global community made an historic commitment to eradicate extreme poverty and improve the health and welfare of the world's poorest within 15 years[5]. One of the United Nations' Millennium Development Goals (MDGs) aims to improve maternal health, with a target of reducing the Maternal Mortality Ratio (MMR) by three quarters between 1990 and 2015. The MDG initiative provides a unique opportunity refocus and accelerate program efforts by donors, governments, and civil society, to improve maternal health for individual and societal well being. Among commonly used human development indicators, maternal mortality shows one of the starkest disparities between developed and developing countries, and between the rich and poor within countries. Moreover the poorest countries are progressing the slowest towards reducing maternal mortality; low income countries have

been reducing maternal mortality by 2.4 percent a year, compared to lower middle income countries (4.9 percent)[6].

South Asia accounts for thirty percent of the world's maternal deaths, with one woman or girl dying from complications of pregnancy and child birth every three minutes. Yet these statistics –owing to mass under reporting- do not even adequately represent the countless number of others who have perished, without a trace in official registry[7].

The National Rural Health Mission (NRHM) of India launched on 12th April, 2005 seeks to reduce the MMR from 407 to 100 per 1,00,000 live births through accessible, affordable and quality health care to the rural population, especially the vulnerable sections[8].

Approximately one-quarter of all pregnancy and delivery related maternal deaths worldwide occur in India, which has the highest burden of maternal mortality for any single country[9]. In 2006, India reported a Maternal Mortality Ratio (MMR) of 254 per 100,000 live births or 85,000 maternal deaths per year[10].

Among Indian States, Tamil Nadu has the second lowest MMR (111 per 100,000live births), after Kerala (95 per 100,000 live births)[10]. In Tamil Nadu, 926 maternal deaths were identified in 2009-10 (MMR 85 per 100,000 live births)[11]. Major interventions to avert maternal deaths include (1) provision of community-based maternity services (2) Emergency Obstetric and New Born Care services (EmONC). In Tamil Nadu, Comprehensive Emergency Obstetric Newborn Care (CEmONC) centres were established in 2004, with the objectives to provide comprehensive emergency obstetric and newborn care on 24x7 basis within half an hour's reach. Subsequently on realizing that basic services to be made widely available,Basic Emergency Obstetric Newborn Care (BEmONC) centres were established in 2006, on 24x7 basis in every block. As a result of these interventions, MMR in Tamil Nadu declined from 134 in 2001-03 to 111 in 2004-06.

Definitions and measures of maternal mortality

The WHO has provided the following definitions and measures related to maternal mortality[12,13].

Maternal death: The death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes[12].

Direct obstetric deaths

Maternal deaths resulting from obstetric complications of the pregnant state (pregnancy, labour, and the puerperium), from interventions, omissions or incorrect treatment, or from a chain of events resulting from any of the above[12].

Indirect obstetric deaths

Maternal deaths resulting from previous existing disease or disease that developed during pregnancy and that was not due to direct obstetric causes but was aggravated by the physiological effects of pregnancy[12].

Measures of maternal mortality

Maternal Mortality Ratio (MMR): The Maternal Mortality Ratio represents the obstetric risk associated with each pregnancy. It is calculated as the number of maternal deaths during a given year per 100,000 live births during the same period[13].

Materanal Mortality Rate: It measures both the obstetric risk and the frequency with which women are exposed to this risk. It is calculated as the number of maternal deaths in a given period per 100,000 women of reproductive age (usually 15-49 years)[13].

Lifetime Risk of Maternal Death: It takes into account both the probability of becoming pregnant and the probability of dying as a result of the pregnancy cumulated across a women's reproductive years[13].

Out of the above three measures Maternal Mortality Ratio is the most commonly used.

Measuring maternal mortality

Maternal mortality is difficult to measure for both conceptual and practical reasons. Maternal deaths are hard to identify precisely because this requires information about deaths among women of reproductive age, pregnancy status at or near the time of death, and the medical cause of death. All three components can be difficult to measure accurately, particularly in settings where deaths are not comprehensively reported through the vital registration system and where there is no medical certification of cause of death. More over even where overall levels of maternal mortality are high, maternal deaths are nonetheless relatively rare events and thus prone to measurement error. As a result, all existing estimates of maternal mortality are subject to greater or lesser degrees of uncertainty. Countries are classified in to four categories broadly. (1) those with complete civil registration and good cause of death attribution (2) those with relatively complete civil registration system in terms of numbers of births and deaths but where cause of death is not adequately classified (3) those with no reliable system of civil registration where maternal deaths like other vital events go unrecorded (4) those with estimates of maternal mortality based on household surveys, usually using the direct or indirect sisterhood methods[14].

Approaches for measuring maternal mortality

Commonly used approaches for obtaining data on levels of maternal mortality vary considerably in terms of methodology, source of data and precision of results. The main approaches are described below.

Vital registration

In developed countries, information about maternal mortality derives from the system of vital registration of deaths by cause. Even where coverage is complete and all deaths medically certified, in the absence of active case finding, maternal deaths are frequently missed or misclassified. In many countries, periodic confidential enquiries or surveillance are used to assess the extent of misclassification and under reporting[14].

Direct household survey methods

Where vital registration data are not appropriate for the assessment of cause-specific mortality, the use of household surveys provides an alternative. However, household surveys using direct estimation are expensive and complex to implement because large sample sizes are needed to provide a statistically reliable estimate. The most frequently quoted illustration of this problem is the household survey in Addis Ababa, Ethiopia, where it was necessary to interview more than 32,000 households to identify 45 deaths and produce an estimated MMR of 480. MMR varied from 370-660, with 95 percent confidence interval[14].

Indirect sisterhood method

The sisterhood method is a survey-based measurement technique that in high fertility populations substantially reduces sample size requirements because it obtains information by interviewing respondents about survival of all their adult sisters. Although sample size requirements may be reduced, the problem of wide confidence interval remains. Furthermore the method provides a retrospective rather than a current estimate averaging experience over a lengthy time period (some 35 years, with a midpoint around 12 years before the survey)[14].

Direct sisterhood method

The Demographic and Health Surveys use a variant of the sisterhood approach, the direct sisterhood method. This relies on fewer assumptions than the original method but it requires larger sample size and the information generated is more complex to collect and to analyse. The direct method does not provide a current estimate of maternal mortality but the greater specificity of the information permits the calculation of a ratio for a more recent period of time. Results are typically calculated for a reference period of seven years before the survey, approximating a point estimate some three to four years before the survey. Because of relatively wide confidence intervals, the direct sisterhood method cannot be used to monitor short term changes in maternal mortality or to assess the impact of safe motherhood programmes[14].

Reproductive age mortality studies

The Reproductive Age Mortality Studies (RAMOS) involves identifying and investigating the causes of all deaths of women of reproductive age. This method has been successfully used in countries with good vital registration system to calculate the extent of misclassification and in countries without vital registration of deaths. Successful studies in countries lacking complete vital registration use multiple and varied sources of information to identify deaths of women of reproductive age; no single source identifies all deaths. Subsequently interviews with household members and health care providers and reviews of facility records are used to classify the deaths as maternal deaths or otherwise. Properly conducted, the RAMOS approach is considered to provide the most complete estimation of maternal mortality but can be complex and time consuming to undertake, particularly on a large scale[14].

Census

A high quality decennial census could include questions on deaths in the household in a defined reference period (often one or two years), followed by more detailed questions that would permit the identification of maternal deaths on the basis of time of death relative to pregnancy (verbal autopsy). Nonetheless the advantages of such an approach are that it would generate both national and sub national figures and that it would be possible to undertake analysis according to the characteristics of the household. Trend analysis would be possible because sampling errors would be eliminated or greatly reduced. A number of countries have used the census to generate maternal mortality figures, and work is underway to assess the extent to which such approaches may prove of value in measuring maternal mortality[14].

Verbal autopsy

Where medical certification of cause of death is not available, some studies assign cause of death using verbal autopsy techniques. To facilitate the identification of causes of death in situations where majority of deaths occur at home, verbal autopsy techniques are used, in which relatives of the deceased person are interviewed regarding the circumstances leading to death. Information on the signs and symptoms preceding the death is used to reconstruct the illness leading to death and assign the most probable cause[15].

In India, the office of the Registrar general under the ministry of home affairs, apart from conducting population census and monitoring of registration of births and deaths, has been evaluating indirectly the impact of governmental programmes/ schemes on fertility and mortality using the Sample Registration System (SRS). SRS is the largest demographic sample survey in the country and is being used to provide direct estimates of maternal mortality through a nationally representative sample. The verbal autopsy instruments are used

for the deaths reported under the SRS on a regular basis to yield cause specific mortality profile in the country[10].

In Tamil Nadu; identification of maternal deaths is the first step in the surveillance process. The state, initiated identification and compulsory reporting of maternal deaths in 1994. It was mandated that each and every maternal death be reported by the village health nurse working at the level of the Health Sub Centre, the medical officers of Primary Health centres, first referral unit (FRU) and non-FRU government hospitals, district public health nurses and Deputy Directors of Health Services. The efficacy of reporting has improved overtime. The apparent increase in the number of maternal deaths between 1994 and 2001 reflects improvements in reporting due to a better surveillance system[16]. Maternal mortality surveillance programme in Tamil Nadu is a combination of medical cause of certification, verbal autopsy, facility based death reviews and multiple sources of notification.

Causes of maternal deaths

Maternal deaths occur throughout pregnancy, labour, childbirth and postpartum. Between 11 percent and 17 percent of maternal deaths happen during childbirth itself and between 50 percent and 71 percent in the postpartum period. The fact that a high level of risk is concentrated during childbirth itself, and that many postpartum deaths are also a result of what happened during birth, focuses attention on the hours and sometimes days that are spent in labour and giving birth, the critical hours when a joyful event can suddenly turn into an unforeseen crisis. The postpartum period-despite its heavy toll of deaths is often neglected. Within this period, the first week is most prone to risk. About 45 percent of postpartum maternal deaths occur during the first 24 hours, and more than two thirds during the first week. Maternal deaths result from a wide range of indirect and direct causes.

Maternal deaths due to indirect causes represent 20 percent of the global total. They are caused by diseases (pre-existing or concurrent) that are not complications of pregnancy, but complicate pregnancy or are aggravated by it. These include malaria, anaemia, HIV/AIDS and cardiovascular diseases. Their role in maternal mortality varies from country to country, according to the epidemiological context and the health system's effectiveness in responding.

The lion's share of maternal deaths is attributable to direct causes. Direct maternal deaths follow complications of pregnancy and childbirth, or are caused by any interventions, omissions, incorrect treatment or events that result from these complications, including complications from (unsafe) abortion. The four other major direct causes are haemorrhage, infection, eclampsia and obstructed labour. The levels of maternal mortality depend on whether these complications are dealt with adequately and in a timely manner. Postpartum haemorrhage (PPH) occurs in 10.5 percent of live births, sepsis in 4.4 percent, pre-eclampsia and eclampsia in 3.2 percent and obstructed labour 4.6 percent. The case fatality rate is 1 for PPH, 1.3 for sepsis, 1.7 for preeclampsia and eclampsia and 0.7 for obstructed labour. Globally in 2000 deaths due to PPH was 25 percent, sepsis 15 percent, eclampsia 12 percent and obstructed labour 8 percent[1].

The leading causes of maternal mortality in developing regions are haemorrhage and hypertension, which together account for half of all deaths in expectant or new mothers. Indirect causes, including malaria, HIV/AIDS and heart disease, result in 18 per cent of maternal deaths. Other direct causes, such as obstructed labour, complications of anaesthesia or caesarean section, and ectopic pregnancy, lead to 11 per cent of all deaths during pregnancy or childbirth. The vast majority of these deaths are avoidable. Haemorrhage, for example, which accounts for over one third of maternal deaths, can be prevented or managed through a range of interventions administered by a skilled health-care provider with adequate equipment and supplies. The causes of maternal deaths in developing regions during 1997-

2007 indicated that haemorrhage contributed to 35% of maternal deaths, hypertension 18%, abortion and miscarriage 9%, sepsis 8%, embolism 1%, other direct causes 11 percent, and due indirect causes 18 percent[17,18].

In India, estimates of causes of maternal deaths have been more reliably studied in the 2001-2003 Special Survey of Deaths. The leading causes of maternal mortality were haemorrhage (38%), followed by sepsis (11%) and abortion (8%). The patterns were similar in all the three categories namely Empowered Action Group (EAG) states and Assam, Southern and Others except that hypertensive disorders and abortion deaths were more in the category Southern and EAG and Assam respectively[19].

Analysis of causes of maternal deaths in Tamil Nadu in 2004, identified haemorrhage (27.3%) as the leading cause of maternal death. Maternal deaths due to preeclampsia and eclampsia was 12 percent, amniotic fluid embolism 8.2 percent, cortical venous thrombosis 5.9 percent, sepsis 5.9 percent, ruptured uterus 3.1 percent, anaemia 23.9 percent, heart diseases 11.3 percent, hepatitis 1.6 percent and others 0.8 percent[20].

Ecological factors associated with maternal deaths

Globally, many of the interventions for reducing maternal mortality are based on the study of ecological factors associated with maternal mortality.

Shiffman identified three theoretical perspectives within the research literature delineating the factors shaping maternal mortality. These include: (1) the wealth or standard of living perspective that suggests declining maternal mortality seems from rising national wealth or GDP per capita; (2) the health perspective focuses upon the potential for institutional efforts to lower maternal mortality by providing greater access to health care services; and, (3) the empowerment perspective argues that low social status afforded women directly contributes to higher maternal mortality. The study on material consumption and social well being found

that ecological footprint consumption has a moderately strong direct influence shaping lower levels of maternal mortality[21].

An ecological analysis of Maternal Mortality Ratios of 84 countries indicated that a greater proportion of deliveries with a skilled attendant and higher contraceptive prevalence rates were both associated with lower national maternal mortality ratios[22].

A study on MMR in Yunnan, China concluded that declines in maternal mortality in Yunnan over 14 years appear to reflect health, social and economic interventions implemented in the 1990s. The association of hospital delivery with maternal mortality may be due to the effective management of severe pregnancy and birth complications. Low income and illiteracy were associated with MMR but primarily through their impact on the use of prenatal and obstetric care[23]. Studies elsewhere in China demonstrated that health interventions that target health infrastructure, quality of obstetric care and health education are effective in reducing MMR[24-25].

An analysis of ecological data sets from 155 countries concluded that maternal deaths were substantially reduced when a high proportion of births were attended by health professionals, including primary health care workers trained in midwifery skills, with the maintenance of an aseptic environment, the identification of maternal and foetal complications, and the opportunity when necessary to transfer parturient mothers to centres with higher level skills and facilities[26].

A recent study of maternal mortality for 181 countries, 1980-2008, found that four powerful drivers of maternal mortality are improving in most countries. First, the global total fertility rate (TFR) has dropped from 3.7 in 1980 to 3.26 in 1990 and 2.56 in 2008. Despite rising numbers of women of reproductive age, the decrease in TFR has kept the size of the global birth cohort stable. In addition to the direct effect of fertility on exposure to risk of maternal

deaths, the MMR and TFR are strongly correlated. Societies in which TFR decreases are also places with declines in the MMR –whether this relation is causal or mediated through social change that drives both is not clear. Second, income per head, which can affect maternal mortality through several channels from nutritional status of mothers to physical and financial access to health care, has been rising particularly in Asia and Latin America. Third, maternal educational attainment, another strong correlate of maternal mortality, has been rising. Finally increase in skilled birth attendance also contributes to the decline in MMR. Further, some large countries like India have witnessed quite rapid increases in skilled birth attendance in recent years[4].

Summary

Globally, substantial, albeit varied, progress has been made towards reducing MMR. Only a handful of countries are on track to achieve the goal set for 2015. As of 2008, six countries (includes India) contribute to more than half of all maternal deaths.

India's NRHM aimed to reduce MMR from 407 to 100 through by targeting rural and vulnerable sections. However, India is yet to achieve that target. Within India, the progress made by the state varied substantially. Tamil Nadu ranks the second lowest MMR and has the best maternal mortality surveillance system.

More than half of the maternal deaths are caused by haemorrhage and hypertension. Major ecological determinants identified through published literature include (1) socio-economic variables such as income and educational status of women (2) improved access to care namely skilled birth attendance or hospital delivery (3) contraceptive prevalence rate and total fertility rate. However, there is lack of such analysis in India.

References

1. Lerberghe WV, Annick Manuel, Zoe Mathews, Cathy Wolfheim. Make every mother and child count: The World Health Report 2005: Geneva: World Health Organization; 2005.

2. WHO. Women and Health: Today's evidence Tomorrow's agenda. Geneva: World Health Organization, 2005.

3. WHO. Beyond the Numbers: Reviewing maternal deaths and complications to make pregnancy Safer. Geneva: World Health Organization; 2004.

4. Hogan MC, Foreman KJ, Naghavi M, Ahn SY, Wang M, Makela SM, Lopez AD, Lozano R, Murray CJ. Maternal mortality for 181 countries, 1980-2008: a systematic analysis of progress towards Millennium Development Goal 5. Online. 2010 April 12; Available from : . Lancet. 2010;375(9726):1609-23.

5. WHO. Health: Millennium Development Goals. Geneva: World Health Organisation; 2005.

6. Geeta Nanda, Kimberly Swittick and Elizabeth Lule. Accelerating progress towards Achieving the MDG to Improve Maternal Health: A Collection of Promising Approaches.Washington: The International Bank for Reconstruction and Development / The World Bank; 2005.

7. UNICEF. Surviving Childbirth and Pregnancy in South Asia. Kathmandu,Nepal: The United Nations Children's Fund; December, 2004.

8. Government of India. National Rural Health Mission: Meeting people's health needs in rural areas: Framework for implementation 2005-2012. New Delhi; Ministry of Health and Family Welfare; 2005

9. Sue J Goldie, Steve Sweet, Natalie Carvalho, Uma Chandra Mouli Natchu, Delphine Hu. Alternative strategies to Reduce Maternal Mortality in India: A Cost-Eeffectiveness Analysis. PLoS Medicine April 2010; vol 7: issue 4.

10. Government of India. Maternal Mortality in India : 2004-2006: Trends, causes and Risk factors. New Delhi: Registrar General of India; April, 2009.

11. Government of Tamil Nadu. Maternal and Child Health Report 2010. Chennai: Directorate of Public Health and Preventive Medicine, Government of Tamil Nadu; 2010.

12. WHO. International Statistical Classification of Diseases and Related Health problems. Tenth revision (ICD-10). Geneva: WHO; 1992.

13.WHO.Reduction of maternal mortality: A joint WHO/UNFPA/UNICEF/World Bank statement. Geneva: World Health Organisation; 1999.

14.WHO. Maternal Mortality in 2000: Estimates developed by WHO, UNICEF, UNFPA.Geneva: World Health Organisation; 2004.

15.WHO. Verbal Autopsies for maternal deaths. Geneva: World Health Organisation; 1994.

16. WHO. Safer pregnancy in Tamil Nadu: from vision to reality. New Delhi; World Health Organisation; 2009.

17. United Nations. The millennium Development Goals Report: 2010. New York: United Nations; 2010.

18. WHO and UNICEF. Countdown to 2015: Decade Report (2000-2010) with country profiles: Taking stock of maternal, newborn and child survival. Geneva: World Health organisation and UNICEF; 2010.

19. Government of India. Maternal Mortality in India: 1997-2003: Trends, causes and Risk factors. New Delhi: Registrar General of India; April, 2009.

20. Reproductive and Child Health Project. An analysis of verbal autopsy reports of maternal deaths: Tamil Nadu,2004. Chennai: Reproductive and Child health Project, Government of Tamil Nadu; 2005

21. Rice J. Material consumption and social well-being within the periphery of the world economy: An ecological analysis of maternal mortality. Social Science Research 2008;37:1292-1309

22. Nancy L Sloan, Beverly Winikolf, and Fariyal F Fikree. An ecologic analysis of maternal mortality ratios. Studies in family Planning 2001; 32 (4): 353-355.

23. J Li, c Luo, R Deng, P Jacoby, N de klerk. Maternal mortality in Yunnan, China : recent trends and associated factors. British journal of Obstetrics and Gynaecology, May 2007.

24.Zhang X, Wang L, Guo S. An analysis of related factors for maternal mortality rate at county level: Zhonghua Yu Fang Yi Xue Za Zhi 200337:342-5.

25. Zhang T ,Wu Y, Zhang X, Xiong Q, Wang Y, Zhao G, et al. An evaluation of effects of intervention on maternal and child health in the rural areas of China. Sichun Da, Xue Xue Bao Yi Xue Ban 2004; 59 695-708.

26. Jane J.A. Robinson and Heather Wharrad. The relationship between attendance at birth and maternal mortality rates: an exploration of United Nation's data sets including the ratios of physicians and nurses to population, GNP percapita and female literacy. Journal of Advanced Nursing 2001, 34 94), 445-455.